International Journal of Technical Research and Applications e-ISSN: 2320-8163,
www.ijtra.com Volume 2, Issue 5 (Sep-Oct 2014), PP. 100-106

ANALYSIS OF GROUNDWATER QUALITY USING STATISTICAL TECHNIQUES: A CASE STUDY OF ALIGARH CITY (INDIA)

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Abstract- The study was conducted to evaluate the groundwater quality of Aligarh city, (India). Groundwater samples were collected from 40 wells and analyzed for 20 water quality parameters in post-monsoon seasons during the year 2013. High coefficient of variance indicates variability of physico-chemical parameters concentrations in ground water. The descriptive statistical analysis was done beside Pearson correlation. From correlation analysis it was observed that very strong correlations exist between total hardness and Mg^{++} (0.99), TDS and total hardness (0.88), TDS and Chloride (0.87). In 100% of the samples recorded alkalinity and magnesium concentration were found higher than maximum permissible limit prescribed by BIS. Concentration of hardness, cadmium, pH, iron, lead, and total dissolved solids were also found above the standard limits prescribed by BIS. This reveals deterioration of water quality. It is therefore, suggested to take up regular monitoring of groundwater in areas of Aligarh city.

Key words: Contamination, Groundwater quality, Multivariate, Physicochemical characteristics, Statistical analysis.

I. INTRODUCTION

ater is blessing of God and is very precious resource of this planet. It is well known that human health and survival depends upon use of uncontaminated and clean water for drinking and other purposes. Most human activities involve the use of water in one way or other such as food, production, nutrition are dependent on water availability in adequate quantities and good quality (Howari F.M., 2005). It is estimated that approximately one third of the world's population uses groundwater for drinking purposes and today more than half the world's population depends on groundwater for survival (Mohrir A., 2002). Data has shown that groundwater were less susceptible to bacterial re growth (Niquette et al. 2001). The water supply for human consumption is often directly sourced from groundwater without biochemical treatment and the level of pollution has become a cause for major concern (Sinha, 2004).

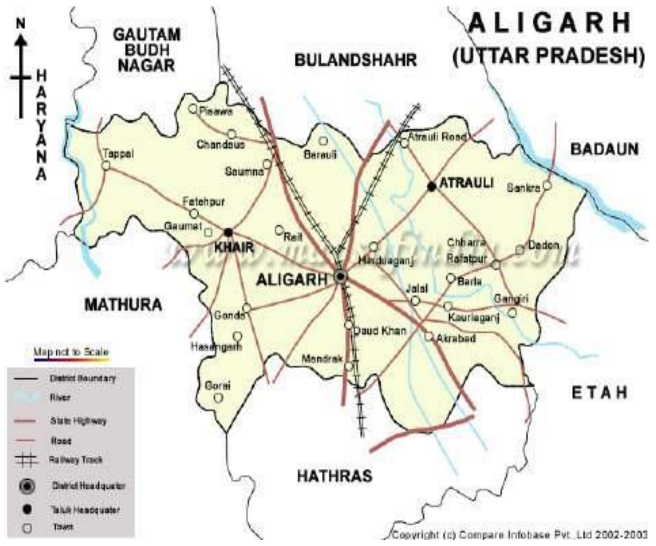
Groundwater resource is under threat from pollution either from human life style manifested by the low level of hygiene practiced in the developing nations (Ikem, A. et al, 2002). With increasing industrialization, urbanization and growth of population, India's environment has become fragile and has been causing concern (Mohapatra and Singh, 1999). Pollution of water is due to increased human population, industrialization, use of fertilizers in agriculture and man made activity (Rao, et al, 2012). Once the groundwater contaminated, its quality cannot be restored by stopping the pollutants from the source therefore it becomes very important to regularly monitor the quality of groundwater.

In this study statistical techniques were used to analyze the water quality data collected from Aligarh City, (India). Correlation coefficient is used to measure the strength of association between two continuous variables. This tells if the relation between the variables is positive or negative that is one increase with the increase of the other. Thus, the correlation measures the observed co-variation. The most commonly used measure of correlation is Pearson's correlation (r). It is also called the linear correlation coefficient because r measures the linear association between two variables (Halsel and Hirsch, 2002).

II. STUDY AREA

The Aligarh is an ancient city in the north Indian state of Uttar Pradesh is situated in the middle of doab-the land between The Ganga and Yamuna rivers, at a distance of 130 Km Southeast of Delhi on the Delhi- Howrah rail route and the Grand Trunk road. Aligarh lies between latitude 27º 54' and 28º north and Longitude is 78º and 78º 5' east. The Aligarh city is spread over an area of about 36.7 km^2. The area lies between the Karwan River in the west and the Senger River in the east and is a part of central Ganga basin. Aligarh is mostly known as a university city where the famous Aligarh Muslim University is located. The Aligarh city is an important centre of lock smithy and brassware manufacturing.There are a total of 5506 industrial units in Aligarh city, of these; there are 3500 small scale industries, 2000 medium scale 6 large industries. Environmental quality of the area deteriorates mainly as a result of the increasing industrial activities. All segments of environment are being polluted by various ways. However, the study of water pollution is selected as it is not an ordinary liquid but is the elixir of life.

Aligarh has a monsoon influenced humid subtropical climate. July is the wettest month. The normal annual rainfall is 760 mm. Maximum temperature shoots upto 47^0C and minimum temperature may fall around 2^0C. The average relative humidity in the morning is 62.25% and in the evening it is 44.2%. Hydrogeologically there is a three to four tier aquifer system. Aquifers seem to merge with each other, thus, developing a single body's aquifer. This makes the aquifer vulnerable to contamination (Khan T. A., 2011).



III. MATERIAL AND METHODS

Forty water samples were collected in post-monsoon (November) seasons during the year 2013. These samples were collected as per the standard methods prescribed for sampling. Plastic bottles of 1.5 liter capacity with stopper were used for collecting samples. Each bottle was washed with 2% Nitric acid and then rinsed three times with distilled water. Samples were analyzed to determine the concentrations of pH, Turbidity, Temperature, Total Dissolved Solids (TDS), Electrical conductivity, Hardness, Chloride, Sulfate, Alkalinity, Fluoride, Iron, Calcium, Magnesium, Nitrate, Zinc, Copper, Lead, Chromium and Cadmium in the laboratory of U.P. Jal Nigam, Aligarh. All the tests were conducted in accordance with the techniques described by American Public Health Association (APHA 2005).

pH was measured by digital pH meter micro processor based model no: LPV 2550 t. 97, 2002 make: HACH USA. Electrical conductivity (EC) and total dissolved solids (TDS) were measured with digital EC-TDS analyzer model No: CM 183, make Elico, India. Turbidity was measured by using Nephalo-meter model No: 2100 Q-01 make: Hach USA. Iron, Nitrate, Sulfate, Fluorides, Calcium, Magnesium, Copper, Zinc, ion concentrations were determined by spectrophotometer, using UV-Vis laboratory spectrophotometer (Model No: DR 5000) make Hach, USA. All the general chemicals used in the study were of analytical reagent grade (Merck/BDH). Standard solutions of metal ions were procured from Merck, Germany, Fisher Scientific, Mumbai and Rankem from RFCL limited, New Delhi. Various statistical analyses of the experimental data were performed using Microsoft Excel 2007.

IV. RESULTS AND DISCUSSION

A. Groundwater chemistry

Groundwater samples were drawn from deep (> 50 m) and shallow wells (<50 m) and analyzed for physico-chemical parameters. The results obtained were evaluated in accordance with the standards prescribed under Indian standard drinking water specification IS: 10500:2012 of Bureau of Indian Standards. The parameters exceeding the BIS permissible limits along with their permissible limits are presented in table-1.

B. Temperature

The maximum water temperature was observed 24^0C at S_{31} and minimum 17^0C at $S_{14}$with an average value of 19.25^0C. The variation in temperature may be due to different timing of collection and influence of season (Jayaraman et al, 2003). Temperature controls behavioral characteristics of organisms, solubility of gases and salts in water, No other factor has so much influence as temperature (Welch 1952).

pH

The pH of a solution is the negative logarithm of Hydrogen ion concentration in moles per liter. pH is dependent on the carbon dioxide-carbonate-bicarbonate equilibrium. pH values ranged and 7.01 to 8.82 with an average value of 8.38,indicating the alkaline nature of water samples. 62.5% of samples were above the standard limit (6.5 to 8.5) prescribed by BIS. Carbon dioxide in groundwater normally occurs at a much higher partial pressure than in the earth's atmosphere. When groundwater was exposed to the atmosphere, CO_2 will escape and the pH will rise. For consumption point of view, all the samples may be considered fit, as they are neither acidic nor strongly alkaline in nature.

C. Total Dissolved Solids (TDS)

A total dissolved solid (TDS) is the concentrations of all the dissolved minerals in water. TDS is used as an indication of aesthetics and general nature of salinity of water. Concentration of dissolved solids is important parameter in drinking water; to ascertain the suitability of the groundwater for any purpose, it is essential to classify the groundwater depending upon its hydro chemical properties based on the total dissolved solids values (Freeze and Cherry 1979). The TDS values in all the study area varies from 224 to 987 mg/l with an average value of 541.38 mg/l in post-monsoon period. In the present study, 42.5% of the samples were exceeding maximum permissible limit (500 mg/l) prescribed by BIS. An elevated level of TDS, by itself, does not indicate that the water present a health risk. However, elevated level of specific ions included in the TDS measurement such as Mg^{++}, Ca^{++}, No_3^-, F^- could present health risk. The concentration of dissolved ions may cause the water to be corrosive, salty or brackish taste, result in scale formation.

D. Turbidity

The turbidity is a measure of the extent to which light is either absorbed or scattered by suspended material in water. The turbidity for all the samples is below the BIS Standards limit 1.0 NTU. The highest value of turbidity is 2.37 NTU. Turbidity in water causes the degradation in the clarity.

Table-1 Parameters exceeding the permissible limit

Serial No.	Parameter	Permissible limit as per BIS IS:10500:2012	Analytical results of samples		Sample exceeding permissible limit	
			Minimum	Maximum	Numbers	%
1	Temperature in ^{0}C	-	17.0	24.0	-	-
2	pH	6.50-8.50	7.01	8.82	25	62.5
3	TDS in mg/l	500.00	224.00	987.00	17	42.5
4	EC in µ mohs/cm	1500.00	378.30	2532.70	13	32.5
5	Turbidity in NTU	1.00	0.05	2.37	01	2.5
6	Iron in mg/l	0.30	0.060	0.61	26	65
7	Nitrate in mg/l	45.00	0.19	25.23	0	0
8	Sulfate in mg/l	200.0	13.20	379.20	14	35
9	Fluorides in mg/l	1.00	0.01	0.71	0	0
10	Chloride in mg/l	250.00	22.00	421.00	12	30
11	Alkalinity in mg/l	200.00	216.00	598.00	40	100
12	T. Hardness in mg/l	200.00	197.00	608.00	39	97.5
13	Calcium in mg/l	75.00	47.00	122.00	20	50
14	Magnesium in mg/l	30.00	34.02	130.25	40	100
15	Copper in mg/l	0.05	0.00	0.19	16	40
16	Zinc in mg/l	5.00	0.01	1.84	0	0
17	Manganese in mg/l	0.10	0.00	0.26	10	25
18	Lead in mg/l	0.01	0.00	0.21	19	47.5
19	Chromium in mg/l	0.05	0.00	0.33	5	12.5
20	Cadmium in mg/l	0.003	0.00	0.48	35	87.5

E. Electrical Conductivity

Electrical conductivity is the measure of capacity of a substance to conduct the electric current. Most of the salts in water are present in their ionic form and capable of conducting current and conductivity is a good indicator to assess groundwater quality. EC is an useful parameter of water quality for indicating salinity hazards. In the study area, EC values varied between 378.3 µmohs/cm to 2532.7 µmohs/cm with an average value of 1005.65 µmohs/cm.

F. Iron

Iron concentrations in this study varied from 0.08 to 0.64 mg/l with an average value of 0.35 mg/l. 65% of samples were found above the standard limit (0.30 mg/l) prescribed by BIS. Iron is a common metallic element found in the earth's crust Iron can affect the flavor and color of food and water. Iron is biologically an important element which is essential to all organisms and present in hemoglobin system.

G. Nitrate

The highest value of Nitrate concentration was 25.23 mg/l with an average value of 6.52 mg/l. All the samples is below the BIS Standards limit 45.0 mg/l. Nitrate-nitrogen (NO_3-N) in groundwater may result from point sources such as sewage disposal systems and livestock facilities, non-point sources such as fertilized cropland.

H. Sulfates

Sulfates were found in the range from 13.2 to 379.2 mg/l with an average value of 149.05 mg/l. In 35% samples the values were found above the standard limit (200 mg/l) prescribed by BIS. The sulfate content in water is important in determining the suitability of water for public and industrial supplies. Higher concentration of sulfate in water can cause malfunctioning of alimentary canal and shows cathartic effect on human beings (M. Lenin Sunder et al. 2008).

I. Fluorides

The fluoride values in the study area ranges from 0.01 to 0.71 mg/l with an average value of 0.25 mg/l. The fluorides concentration in all the samples is below the BIS standards limit 1.0 mg/l. Fluoride is beneficial for human beings as a trace element, this protects tooth decay and enhances bone development.

J. Chlorides

Chloride occurs in all natural waters in widely varying concentrations. The chloride contents normally increases as the mineral contents increases (Dubey, 2003). Chlorides concentrations ranged from 22.0 to 421.0 mg/l with an average value of 156.33 mg/l. In 30% sample wells, the chloride values exceeded the maximum limit (250 mg/l) prescribed by BIS. At concentration above 250 mg/l, water acquires salty taste which is objectionable. However no adverse health effects on humans have been reported from intake of water containing highest content of chloride (Amrita Singh et al., 2011). If the water with high chloride concentration is used for construction purpose, this may corrode the concrete.

K. Alkalinity

Alkalinity is the measure of the capacity of the water to neutralize a strong acid. The Alkalinity in the water is generally imparted by the salts of carbonates, silicates, etc. together with the hydroxyl ions in free state. Most of the natural waters contain substantial amounts of dissolved carbon dioxide, which is the principal source of alkalinity. The alkalinity varies from 216 to 598 mg/l. 100% samples were found above the standard limit (200 mg/l) prescribed by BIS. The alkalinity values were found increasing in the post monsoon period, compared to the pre-monsoon period in almost all the wells. This may be due to the movement of pollutants into the ground water during rainfall season. The most prevalent mineral compound causing alkalinity is calcium carbonate, which can come from rocks such as limestone or can be leached from dolomite and calcite in the soil. Large amount of alkalinity imparts a bitter taste to water. Large amount of alkalinity in water imparts a bitter taste to water.

L. Total Hardness

Total hardness is a measure of the capacity of water to the concentration of calcium and magnesium in water and is usually expressed as the equivalent of $CaCo_3$ concentration. In the study, the total hardness of the water samples ranges between 197 to 608 mg/l. 97.5% of samples were found above the standard limit (200 mg/l) prescribed by BIS. Hard water is not a health hazards. In fact, the National Research council states that the hard drinking water generally contributes a small amount toward total calcium and magnesium human dietary needs. In some instances, where dissolved calcium and magnesium are very high, water could be a major contributor of calcium and magnesium to the diet. Hard water is useful in the growth of children, if within the permissible limit. However, hard water is a nuisance because of mineral buildup on fixtures and poor soap /detergent performance. The high degree of hardness in the study area can definitely be attributed to the disposal of untreated, improperly treated sewage and industrial wastes.

M. Calcium

The Calcium concentrations were varied from 47 to 122 mg/l. 50% of samples were found above the standard limit (75 mg/l) prescribed by BIS. Calcium (Ca^{2+}) is an important element to develop proper bone growth. It is found in alkaline in nature. Calcium content is very common in groundwater, because they are available in most of the rocks, abundantly and also due to its higher solubility.

N. Magnesium

A large number of minerals contain magnesium; Magnesium is washed from rocks and subsequently ends up in water. Magnesium has many different purposes and consequently may end up in water in many different ways. Chemical industries add magnesium to plastics and other materials as a fire protection measure or as filler. It also ends up in the environment from fertilizer application and from cattle feed. The values of magnesium from groundwater ranged between 36.45 to 118.1 mg/l. In all the well locations, the values of magnesium exceeded the limit (30 mg/l) prescribed by BIS and this indicates the hardness of water.

O. Copper

The Copper concentrations were varied from 0.004 to 0.186 mg/l. 40% of samples were found above the standard limit (0.05 mg/l) prescribed by BIS. Copper is an essential element in the human being for metabolism. Human being especially requires copper as a trace element in the formation of R.B.C and some enzymes. 0.05 m/L are not generally regarded as toxic as but more than 1.5 mg/L may cause sickness and in extreme cases liver damage (Marwari, et al, 2012).

P. Zinc

The zinc concentrations were varied from 0.009 to 1.836 mg/l. It can be observed that all the samples having Zinc value below 5.0 mg/l fall within the limits. Zinc compounds are astringent, corrosive to skin, eye and mucus membrane. They cause special type of dermatitis known as 'Zinc pox'.

Q. Manganese

Manganese was one of the most abundant metals in the earth's crust and usually occurs together with iron (Khan M. M. A., et al, 2010). Manganese concentration in water samples ranged between 0.001 to 0.255 mg/l. In 25% of samples Manganese concentration were found above the standard limit (0.10 mg/l) prescribed by BIS. Manganese concentrations as low as 0.05 mg/L can cause color problems.

R. Lead

The lead concentrations in the water samples were ranged between 0.001 to 0.21 mg/l. In 19 sampling locations, the value of lead exceeded the limit (0.01 mg/l) prescribed by BIS. In 47.5% of samples lead concentration were found above the standard limit (0.01 mg/l) prescribed by BIS. Lead is one of the hazardous and potentially harmful polluting agents. It has impact on man and animals. Lead poisoning symptoms usually develop slowly. It inhibits the formation of hemoglobin by reacting with SH group and interfering with many enzyme functions (Sabhapandit P., et al. 2011).

S. Chromium

The chromium concentration in the study area was found between 0.001 to 0.328 mg/l with an average value of 0.03 mg/i. In 12.5% samples the value of chromium exceeded the limit (0.05 mg/l) prescribed by BIS. Chromium and chromate are known to be potential carcinogenic and chromate are known to be potential carcinogenic substance for lung and nose cancer. Chromates act as irritant to the eyes, nose and throat in traces and chronic exposure with high concentration lead to liver and kidney damage (Marwari, et al, 2012).

T. Cadmium

The Cadmium concentration of water samples were varied from 0.001 to 0.480 mg/l. In 87.5% samples Cadmium exceeded BIS permissible limit (0.003 mg/l). Cadmium in high concentration is harmful, but small amounts of cadmium taken over for a long period also bio-accumulates in the body and cause serious illness (Sabhapandit P., et al. 2011).

U. Statistical analysis

The data were subjected to normal distribution analysis and Pearson correlation Microsoft Excel 2007. Normal distribution analysis (involved mean, median, standard deviation, skewness and kurtosis) analysis is an important statistical tool for identifying the distribution patterns of the different water quality parameters in groundwater samples.

Correlation coefficients of various parameters analyzed were calculated. These Correlation coefficients values were used in estimating the values of other parameters at the particular place without actually measuring them (Mishra, et al, 2003). Pearson correlation analysis is an approach, which provides intuitive similarity relationship between any one sample and entire data set. Pearson's correlation coefficient is usually signified by r (rho), and can take on the values from -1.0 to 1.0. Where -1.0 is a perfect negative (inverse) correlation, 0.0 is no correlation and 1.0 is a perfect positive correlation. The variables having coefficient value (r) > 0.5 or < -0.5 are considered significant.

Table-2 Statistical analysis post-monsoon 2013

	Temp.	**pH**	**TDS**	**EC**	**Turb.**	**Iron**	**NO_3**	**SO_4**	**F**	**Cl^-**
Mean	19.85	8.38	541.38	1005.65	0.49	0.35	6.52	149.05	0.25	156.33
Variance	4.03	0.15	67895.4	353810	0.16	0.03	30.58	15161.21	0.05	17634.69
SD	2.01	0.39	260.57	594.82	0.40	0.17	5.53	123.13	0.23	132.80
Skewness	0.32	-1.97	0.56	1.08	2.88	-0.23	1.15	0.62	0.70	0.83
Kurtosis	-0.79	4.25	-1.24	0.13	12.62	-1.33	1.98	-1.26	-1.05	-0.82
Median	20.00	8.53	454.50	776.75	0.41	0.38	5.76	90.15	0.13	100.00
Mode	18.00	8.62	345.00	#N/A	0.31	0.51	#N/A	#N/A	0.08	54.00
	Alka.	**TH**	**Ca^{++}**	**Mg++**	**Cu**	**Zn**	**Mn**	**Pb**	**Cr^{+6}**	**Cd**
Mean	353.23	397.20	77.25	77.75	0.04	0.39	0.05	0.01	0.03	0.04
Variance	7553.5	18688.0	326.76	911.84	0.00	0.17	0.00	0.00	0.00	0.01
SD	86.91	136.70	18.08	30.20	0.04	0.41	0.07	0.03	0.05	0.09
Skewness	0.57	0.21	0.58	0.27	2.01	2.25	1.95	5.87	4.34	4.13
Kurtosis	0.16	-1.51	-0.32	-1.42	4.55	5.75	3.20	36.05	22.17	19.19
Median	350.00	357.00	72.00	69.01	0.03	0.26	0.02	0.01	0.02	0.01
Mode	380.00	332.00	81.00	46.66	0.02	0.08	0.02	0.00	0.00	0.01

Table 2 indicates the normal distribution analysis pattern of different water quality parameters, where, significant variations between mean and median for parameters, viz. temperature, TDS, EC, Cl^-, SO_4^{--} ,F^-, alkanity, hardness, $Ca^{++,}$ Mg^{++}, $NO_3^-$and Zn^{++} were observed. It indicated that these parameters were not found to be completely distributed in a normal (almost normal) and symmetric way in the samples. However, small difference of mean and median for parameters pH, turbidity, Fe, Cu, Mn, Pb, Cr and Cd, indicated that these parameters were seemed to be distributed normally in groundwater samples. Parameters temperature, TDS, Fe, Cl^-, SO_4^{--} ,F^-,pH, TDS, and EC in the collected samples had negative values of Kurtosis, which indicated that, the distribution of these parameter have flat peak compared to normal distribution pattern. The negative values of skewness of pH (-1.97) and Fe (-0.23) indicated that the data were distributed towards the lower values or having a negative tail in the negative direction. The skewness values for Temp. (0.32), TDS (0.56),EC(1.08),turbidity(2.88), NO_3^- (1.15) were positive, indicated their tail distributed towards the higher values which pointed out that data were distributed in the right direction of the tail.

Correlation among water quality parameters greatly facilitates the task of rapid monitoring of water quality. Table 3 presents the Pearson correlation coefficient matrix between major chemical parameters of ground water of the study area. The variables having coefficient value (r) > 0.50 are considered significant.

The analytical data showed close significant positive association of TDS with EC(r=0.93), Turbidity (0.50), SO_4^{--} (r=0.81), Cl^- (r=0.87), alkalinity(r=0.71), total hardness (r=0.88), Ca^{++} (r=0.72), Mg^{++} (r=0.87), Cd (r=0.50). It indicates that TDS was increased with increasing these parameters in ground water samples. EC with Sulfate (r=0.80), Chloride (r=0.83), Alkalinity (r=0.71), Total hardness (r=0.82), calcium (r=0.64), Mg^{++} (r=0.81). It indicates that EC was increased with increasing these parameters in ground water samples, Turbidity with TDS alkalinity (0.52). SO_4^{--} with TDS EC (r=0.80), Cl^- (r=0.78), alkalinity (r=0.61), total hardness (r=0.73), Ca^{++}(r=0.64), Mg^{++} (r=0.71). Cl^- with Alkalinity (r=0.61), total hardness (r=0.76), Ca^{++}(r=0.59), Mg^{++} (r=0.75), Cd (r=0.51). It indicates that Cl^- was increased with increasing alkalinity, total hardness, Ca^{++}, Mg^{++}, Cd in ground water samples.

Pb and F^- content also showed negative correlation with almost all parameters. pH content showed negative correlation with TDS, EC, turbidity, SO_4^{--} , $Cl^{-,}$ alkalinity, total hardness, Ca^{++} , Cu^{++},Zn, Pb, Cr and ,Cd. Fe^{++}content showed negative correlation with Temperature, TDS, EC, turbidity, NO_3^-, SO_4^{--}, Cl^-, alkalinity, total hardness, Ca^{++}, Mg^{++} , Cu^{++}, Mn, Pb, ,Cr, Cd. It reflects a decreasing trend in Fe^{++} values of groundwater due to increasing Temperature, TDS ,EC, turbidity , NO_3^-,SO_4^{--}, Cl^- , alkalinity, total hardness, Ca^{++} ,Mg^{++}, Cu^{++},Mn, Pb, Cr , Cd . Bangar et al (2008) also observed a highly significant negative correlation coefficient between pH and SO_4^{--},EC, Ca^{++}, Cl^-, SO_4^{--}. This indicates that these variables have an inverse relation.

Table-5.Pearson correlation between different water quality parameters post-monsoon 2013

	Temp.	**pH**	**TDS**	**EC**	**Turb.**	**Iron**	**No_3**	**So_4**	**F**	**Cl^-**
Temp.	1.00									
pH	0.20	1.00								
TDS	0.18	-0.20	1.00							
EC	0.17	-0.17	0.93	1.00						
Turbidity	0.13	-0.23	0.50	0.46	1.00					
Iron	-0.08	0.22	-0.67	-0.62	-0.05	1.00				
Nitrate	0.30	0.22	0.37	0.37	0.16	-0.12	1.00			
Sulphate	0.20	-0.32	0.81	0.80	0.44	-0.61	0.32	1.00		
Fluorides	-0.22	0.01	-0.37	-0.40	-0.42	0.26	-0.24	-0.47	1.00	
Chloride	0.16	-0.12	0.87	0.83	0.40	-0.69	0.30	0.78	-0.39	1.00
Alkalinity	0.24	-0.12	0.71	0.71	0.52	-0.46	0.35	0.61	-0.18	0.61
TH	0.15	-0.11	0.88	0.82	0.38	-0.58	0.45	0.73	-0.42	0.76
Calcium	0.18	-0.25	0.72	0.64	0.42	-0.46	0.49	0.64	-0.19	0.59
Mg	0.13	-0.08	0.87	0.81	0.35	-0.58	0.42	0.71	-0.44	0.75
Copper	-0.10	-0.19	-0.05	-0.001	-0.09	-0.18	-0.14	-0.10	-0.16	-0.04
Zinc	0.01	-0.43	-0.004	-0.03	0.02	0.04	-0.10	0.07	-0.09	-0.07
Mn	0.06	0.01	0.46	0.45	0.26	-0.20	0.10	0.36	-0.27	0.31
Lead	0.06	-0.20	-0.12	-0.09	-0.06	-0.19	-0.18	-0.12	-0.12	-0.11
Chromium	-0.06	-0.19	0.29	0.42	0.10	-0.28	0.16	0.28	-0.21	0.30
Cadmium	-0.19	-0.05	0.50	0.42	0.14	-0.46	0.22	0.37	-0.23	0.51
	Alka.	**TH**	**Ca^{++}**	**Mg++**	**Cu**	**Zn**	**Mn**	**Pb**	**Cr^{+6}**	**Cd**
Alkalinity	1.00									
TH	0.61	1.00								
Calcium	0.66	0.72	1.00							
Mg	0.57	0.99	0.65	1.00						
Copper	-0.15	-0.05	-0.09	-0.04	1.00					
Zinc	-0.08	0.07	0.07	0.07	0.42	1.00				
Mn	0.14	0.38	0.35	0.36	-0.09	-0.11	1.00			
Lead	-0.13	-0.11	-0.16	-0.09	0.61	0.11	-0.06	1.00		
Chromium	0.37	0.21	0.21	0.20	0.22	-0.03	0.22	0.01	1.00	
Cadmium	0.13	0.38	0.42	0.36	0.20	-0.05	0.51	-0.03	0.39	1.00

V. CONCLUSION

The present study clearly reveals that all the water sources chosen for study are not managed suitably for the utilization of water. From the present study the following conclusions were drawn:-

- In all places alkalinity were found above the standard limit (200 mg/l) prescribed by BIS, reveals that the groundwater of the study area is alkaline in nature.
- The Ca^{++} and Mg^{++} ion and total hardness values were high in most of the places, reveals that groundwater of the study area is hard to very hard.
- The Fe^{++} values were high in most of the places.
- The correlation matrix indicates that the TDS is mainly controlled by SO_4^{--},Cl^-, alkalinity, total hardness, $Ca^{++}$and Mg^{++}.There is a strong positive relationship between TDS and these parameters.
- pH content showed negative correlation with TDS, EC, turbidity, SO_4^{--} , Cl^- , alkalinity, total hardness, Ca^{++} , Cu^{++},Zn, Pb, Cr and ,Cd.

  There is an immediate and urgent need for the implementation of a better water quality management policy incorporating the following recommendations.
- Tube wells and other drinking water sources should be installed in a safety place.
- A proper planning and management is required to mitigate the problem of drinking water contamination in the study area.

ACKNOWLEDGEMENTS

The authors are thankful to the Head of Civil Engineering Department, Maharishi Markandeshwar University, Mullana, Ambala for support and facilities provided. They also thankful to Dr Taqveem Ali Khan, Associate Professor Department of Geology, AMU Aligarh India for helping in bringing out the paper in the present form. The author is also thankful to Er Mohammad Owais, Executive Engineer U.P. Jal Nigam Aligarh for providing necessary facilities.

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